Quantum Percolation on the Square Lattice I

Martin Greven, Stanford University, DMR Award 9985067

The study of randomness in complex quantum many-body systems is at the forefront of physics research, but there exist relatively few model systems in which to study such disorder experimentally.

We have found that substitution of magnetic Cu with non-magnetic Zn or Mg in the material La_2CuO_4 provides a model system for studying site percolation in an important quantum many-body system, the two-dimensional Heisenberg antiferromagnet [1,2]. High-quality single crystals were grown at Stanford University and then measured by means of neutron scattering at the NIST Center for Neutron Research.

The experimentally measured spin correlation length, the distance over which magnetic moments “talk” to each other, is found to quantitatively agree with numerical quantum Monte Carlo simulations, clearly demonstrating the model nature of our crystals. These results provide an important basis for the development of a satisfactory theory of the simultaneous effects of disorder and quantum fluctuations.

Using Monte Carlo simulations, we were able to extend our study beyond the experimental system by introducing a bilayer coupling between two single layers, which can tune the strength of quantum fluctuations [3]. Using this technique, we have been able to show that the single-layer system at the percolation threshold is close to, and strongly influenced by, a new quantum multicritical point for the diluted bilayer.

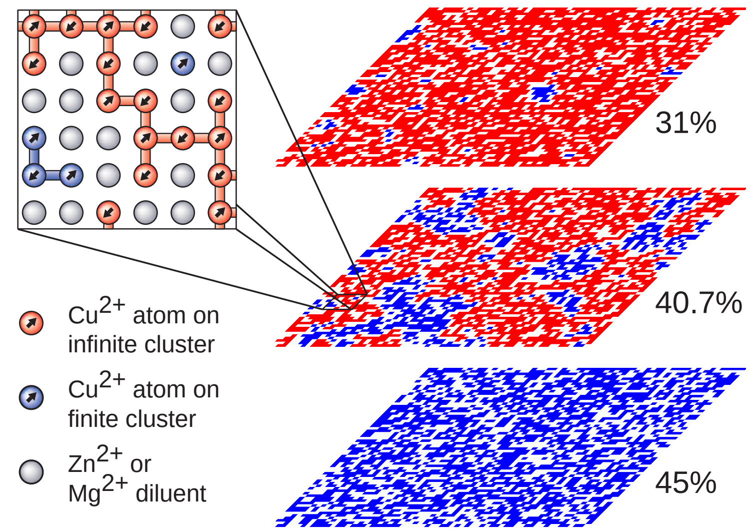

Figure 1: Schematic of a square lattice at site dilution concentrations below (31%), near (40.7%), and above (45%) the percolation threshold (~ 40.72%) where all clusters are disconnected. Sites on the infinite cluster are shown in red, sites on finite disconnected clusters are blue, and diluents are in white. The inset is a close-up view showing the role that magnetic Cu and non-magnetic Zn/Mg ions play in the experimental system.

Quantum Percolation on the Square Lattice II
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References:

[1] O.P. Vajk *et al.*, Science **295**, 1691 (2002).
[2] O.P. Vajk *et al.*, Sol. State Comm. **126**, 93 (2003).
[3] O.P. Vajk and M. Greven, Phys. Rev. Lett. **89**, 177202 (2002).

Educational:

2 undergraduate students

2 graduate students

A course for undergraduate and graduate students has been developed which discusses the important experimental tools of X-ray and neutron scattering and emphasizes current "hot topics" in materials physics. Student tours of the Stanford Synchrotron Radiation Laboratory have been organized.

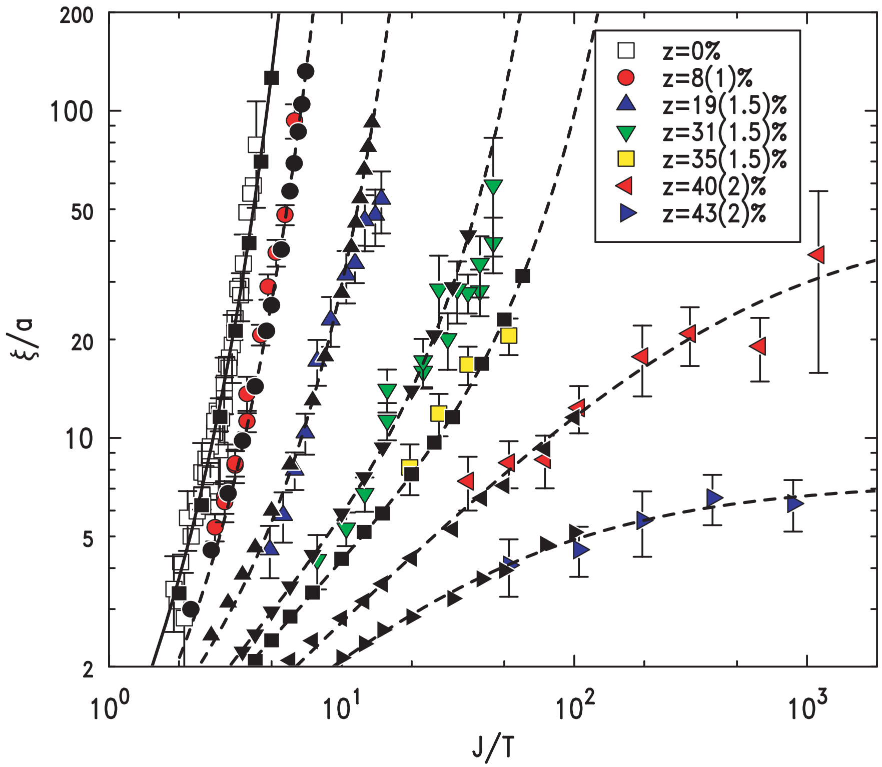

Figure 2: Spin correlation length (in units of the lattice constant) vs. inverse temperature (scaled by the nearest-neighbor antiferromagnetic Cu-Cu coupling *J* of the pure system) for different concentrations of non-magnetic ions. Colored symbols are experimental results from neutron scattering. Black filled symbols are numerical results. The lines are fits to a heuristic theoretical form.